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(54) Positron emission transaxial tomography apparatus

(57) Positron emission transaxial tomography apparatus comprises respective matrices 1 to 6 of detectors TPM_{ij}, as corresponding sides of a polygonal arrangement about an examination region, each matrix being associated with a corresponding photon conversion element CS_i and optical coupling member GO_i. The summed output from each detector matrix (1) is connected to a corresponding set of coincident circuits e.g. CCT_{13}, CCT_{14}, CCT_{15} which are also connected to oppositely located detector matrices 3, 4, 5. If a coincidence is detected, the barycentre (linear) for the detector line array, is determined by a weighting circuit, not shown, from the detector signals after integration, to provide position data which is fed to an a—d converter, and the event is recorded in a memory. Any signal outside an energy window centered at 0.511 Mev is rejected. Tracer events are mapped as occurring on line paths across a sectional region, and the total numbers of events for each path, is stored in a memory M. The distribution of tracer throughout the body section is then computed.

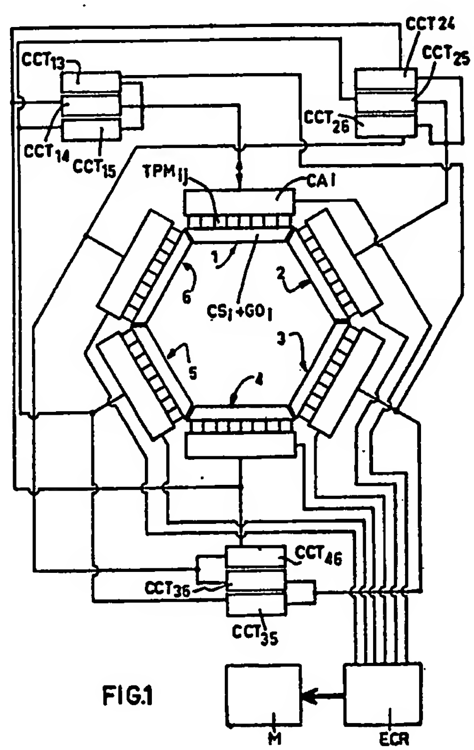

FIG.1

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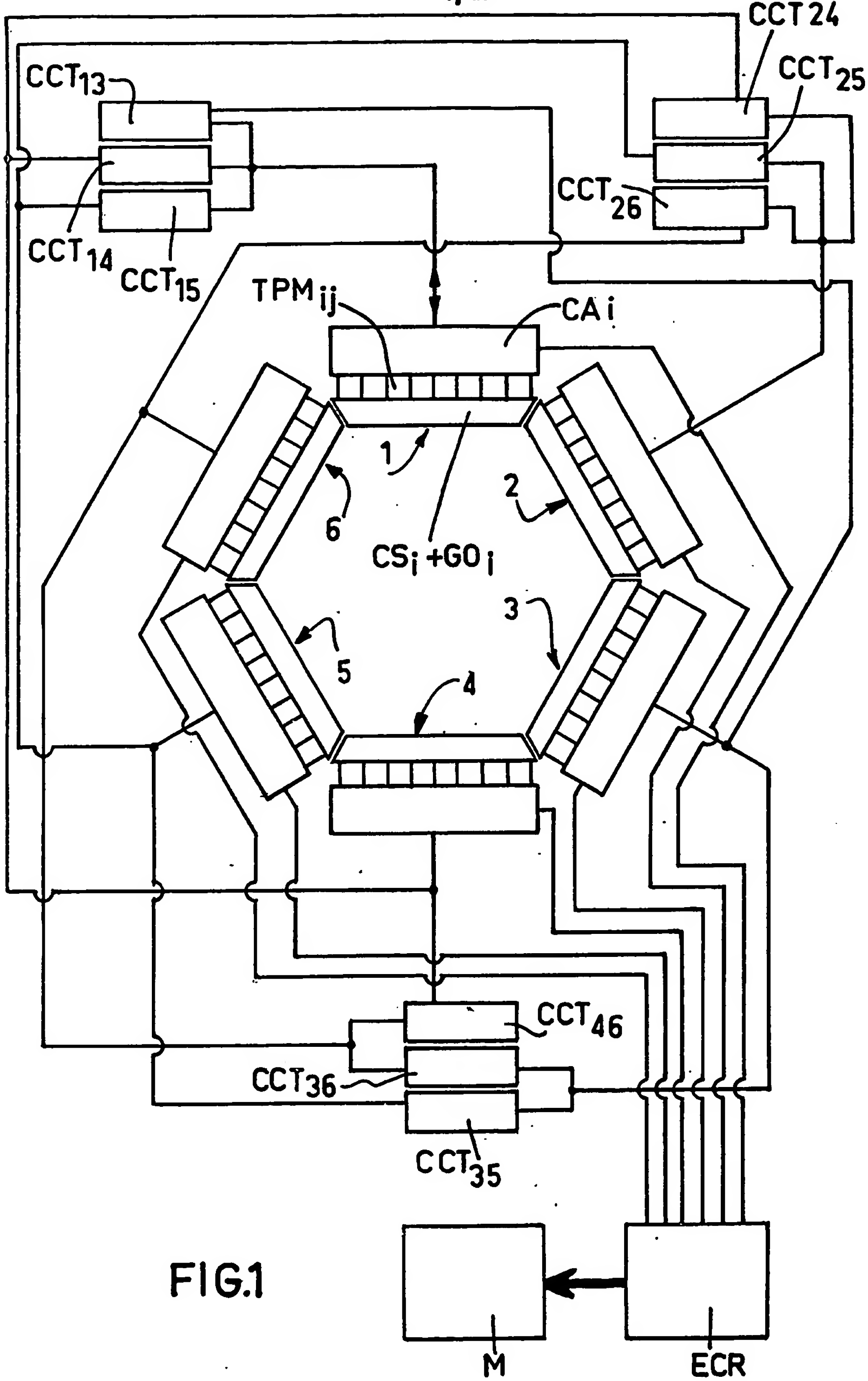
CCT 24
CCT25
CCT13
CCT26
CCT14
CCT15
TPMij
CAi
1
2
6
CSi +GOi
3
5
4
CCT46
CCT36
CCT35
M
ECR

FIG.1

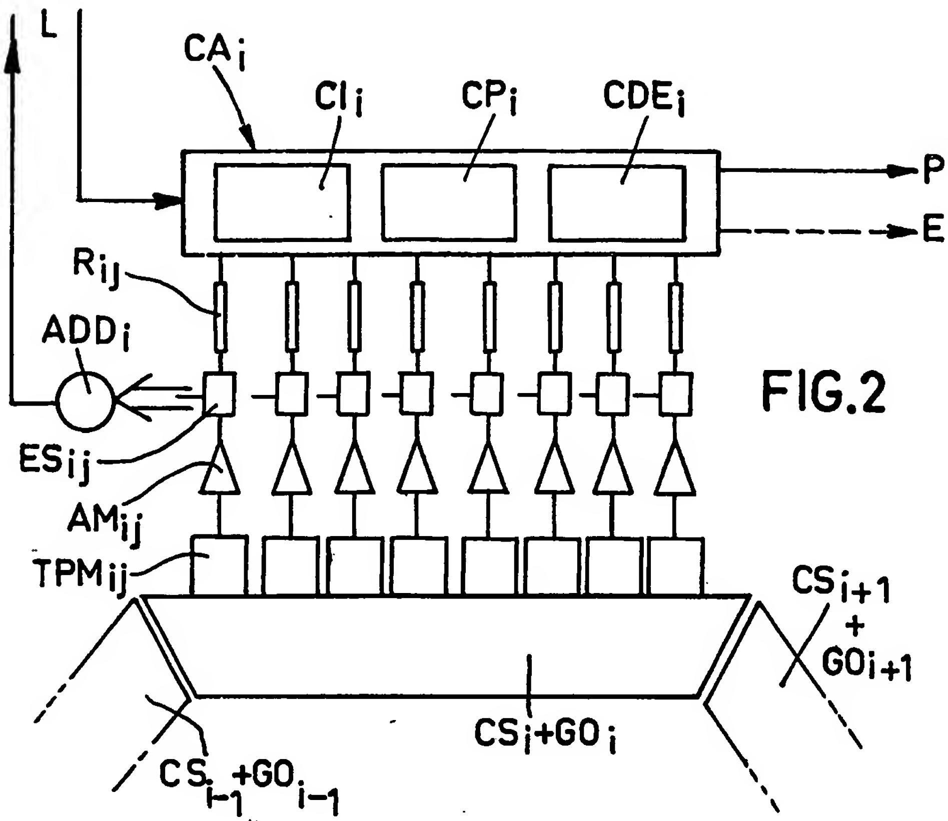
L
CAi
CIi
CPi
CDEi
P
E
Rij
ADDi
ESij
AMij
TPMij
CSi+1 + GOi+1
CSi+GOi
CSi-1 +GOi-1

FIG.2

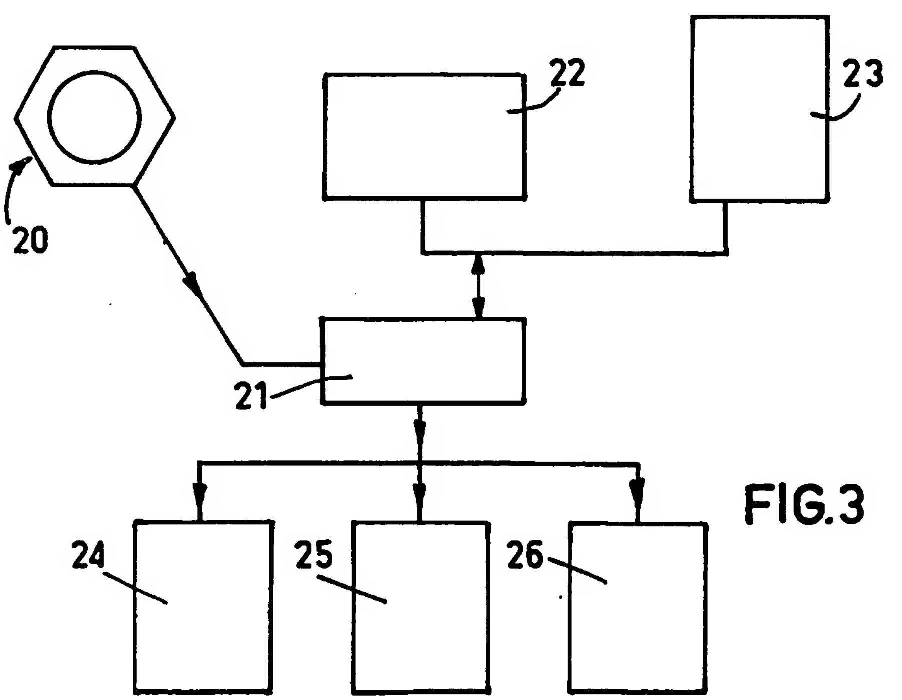
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FIG.3

SPECIFICATION
Positron emission transaxial tomography apparatus

The invention relates to positron emission transaxial tomography apparatus, comprising detector means which comprises a plurality of detector matrices, each detector matrix forming a corresponding side of a polygonal arrangement of said detector matrices surrounding an object region to be examined, and an electronic signal processing means which include coincidence, integration and discrimination circuits for forming an image of at least one sectional region of the object.

An apparatus of this kind is known from United States Patent Specification 3,970,853 and is particularly suitable for making diagnostic sectional images by means of position annihilation measurements, where a radioactive isotope tracer element is introduced into a part of a body to be examined, said radioisotope causing, on decay, the emission of two photons of 0.511 MeV in opposite directions by positron annihilation. Known substances in this respect, are for example, C11, N13, 015 and F18. It is a property of these substances that they tend to be concentrated within abnormalities inside the body. Rotation of a detector device about the body under examination, during which the photon emission is measured in many directions, enables a computer to calculate a density distribution of the radioisotope in the relevant section of the body and this distribution is displayed, for example, on a monitor.

The Journal of Nuclear Medicine, Vol. 16, No. 12, pages 1166—1173 described a similar form of such apparatus which utilizes a ring of detectors arranged around the patient under examination. Due to the size of the individual detectors thereof, the resolution of such apparatus is insufficient for many forms of examination. The detection efficiency of this type is, however, substantially higher than that of apparatus comprising rotating detectors.

The invention has for an object to combine the advantages of the two types of apparatus, while endeavouring to overcome the drawbacks of each apparatus.

According to the invention there is provided positron emission transaxial tomography apparatus, comprising detector means which comprise a plurality of detector matrices, each detector matrix forming a corresponding side of a polygonal arrangement of said detector matrices surrounding an object region to be examined, and electronic signal processing means, which include coincidence, integration and discrimination circuits for forming an image of at least one sectional region of the object, characterized in that each of the detector matrices of the detector means is associated with a corresponding photon conversion element which is common to all the detectors of said matrix.

In a preferred embodiment, each photon interception element forms part of a gamma camera associated with an adapted signal processing device. Such a gamma camera is described, for example, in British Patent Specification 1,529,823; however, it may alternatively be constructed as a cross-bar camera as described in British Patent Specification 1,159,347.

For an efficient use of the detectors, signals which appear in the case of coincidence are preferably applied directly to the signal processing device for position calculation of the annihilation event, after which the position calculation device is reset to a zero position. The signals to be measured are thus integrated only in a subsequent processing part of the device.

The detector means may comprise either an even or an odd number of detector matrices. In the case of an even number of detector matrices, a coincidence circuit is arranged between oppositely situated matrices; in the case of an odd number of detector matrices, a respective coincidence circuit is preferably connected between a matrix and each of the two most immediately opposite matrices. In many cases the detector matrices advantageously comprise a single linear series of detector elements.

An embodiment of the invention will now be described by way of example, with reference to the accompanying diagrammatic drawings, of which:—

Figure 1 illustrates the arrangement of a detection device in accordance with the invention, in the form of a regular hexagonal structure and associated circuits,

Figure 2 is a schematic detail illustrating one of the detection matrices, and

Figure 3 illustrates schematically the computer processing system associated with the hexagonal structure formed by the detection devices.

The embodiment of a tomography apparatus in accordance with the invention, which is shown in the Figures, comprises mainly a set of six detection matrices 1 to 6, each of which occupies one side of a regular hexagonal structure within which a sectional region of an object under examination (not shown) is located. Each of the six devices 1 to 6, being mounted so as to be stationary relative to said object, comprises (see Figure 2) a scintillation crystal CS_i which is optically coupled, *via* an optical coupling member GO_i, to a given number (in this case eight) of photomultiplier tubes TPM_{ij} (the index i may vary from 1 to 6, depending on the relevant detection matrix, while the index j may vary from 1 to 8 when use is made of eight tubes). *Via* amplifier circuits AM_{ij}, isolating stages ES_{ij}, and resistors R_{ij}, the outputs of the eight tubes TPM_{ij} are connected to an arithmetic unit CA_i for calculating the position and the energy. Said arithmetic unit CA_i comprises a circuit CI_i for integrating the signals supplied by the tubes TPM_{ij}, a circuit CP_i for the weighted combination of said signals to determine the barycentre of a group of detector signals and hence the location of the corresponding

scintillation in the crystal CS_i relative to the detectors, and an energy discrimination circuit CDE_i for eliminating those signals whose energy is situated outside an energy window centred around 0.511 MeV.

The detection matrices 1 to 6 cooperate with nine time-coincidence circuits CCT_{13}, CCT_{14}, CCT_{15}, CCT_{24}, CCt_{25}, CCT_{26}, CCT_{35}, CCT_{36} and CCT_{46} (see Figure 1 and also, in Figure 2, which shows one of the connections L between these time-coincidence circuits and the assembly illustrated in Figure 2 and formed by the detection matrix and cooperating arithmetic units). The double index after the reference CCT denotes the detection matrices (1 to 6) between which said time-coincidence circuits are respectively connected: for example, the circuit CCT_{24} serves to supply a validation signal only when the detection matrices 2 and 4 simultaneously detect a photon. If this condition is satisfied, the validation signal is supplied by the circuit CCT_{24} (in this case) and respectively, *via* connections of the kind indicated by L in Figure 2, and is directly applied to said position arithmetic units CA_2 and CA_4 of the corresponding coincidence detection matrices in order to terminate the calculation of the addresses of the detected signals. If the said condition of terminate the calculation of the addresses of the detected signals. If the said condition of coincidence is not satisfied, the output signals of the detection matrices are not taken into account. The reference ADD_i denotes an adder whose inputs are connected, *via* isolating stages ES_{ij}, to the outputs of the amplifiers AM_{ij}, the output of said adder being connected to the time-coincidence circuits associated with the relevant detection matrices.

In the case of validation, the integration performed by the circuits CI_i is completed; if there is no validation, the integration is almost instantaneously interrupted. In both cases the integrating circuits CI_i should be quickly discharged in order to ensure that the detection matrices become available for further detections as quickly as possible. This can be realized, for example, by adding a discharge circuit to each integration circuit, for example, of the type described in French Patent Application No. 7,835,600 filed on December 18, 1978; in these circuits the discharge occurs quickly, independently of the amplitude of the detected signal, and also substantially completely (i.e. without residual charge which could falsify a subsequent integration).

The two calculated addresses, corresponding to each detected photon, represent useful data which are applied to a buffer memory M *via* an analog-to-digital converter ECR which also serves for controlling the data flow. Upon completion of the overall tomographic examination, the number of events detected from an arbitrary, given direction and along each of a set of paths parallel to that direction across the body section can be determined by reading M, and an image of the body section under examination, can be reconstructed. The set of data thus accumulated in the memory M from the detection of γ-photon pairs resulting from the annihilation of positrons in the given directions, is thus used in a signal processing system as shown in Figure 3 for reconstructing an image of the body section under examination, or the respective images of parallel body sections, by means of one of the customary reconstruction algorithms which are well known and which will not be elaborated herein.

Said processing system comprises a computer 21 for processing the data supplied by the hexagonal structure 20 comprising the detection matrices, and an assembly formed by the associated circuits, and also comprises peripheral apparatus, namely a disc memory 22, a magnetic tape memory 23, a printing device 24, a control console 25, and a display unit 26 (also enabling photographs to be made).

In the embodiment described with reference to the Figures 1 to 3, each of the detection matrices 1 to 6 is a gamma camera, and the energy associated with a detected photon is therefore evaluated by the weighted combination of the corresponding signals supplied by the photomultiplier tubes TPM_{ij} of the camera, said calculation being performed individually for each of the detection matrices by the associated arithmetic unit CA_i (see Figure 2 in which the energy data is made available *via* a connection E, whilst the position data is made available *via* a connection P).

Obviously, the invention is not restricted to the foregoing embodiment which can also serve as a basis for other embodiments and other modes of operation, without departing from the scope of the appended claims.

Instead of using gamma cameras, the continuous position detection matrices can alternatively comprise detectors of the wire-chamber type comprising an energy converter, or a gamma camera of the type including a solid state detector; the latter device is also suitable for forming the polygonal detection structure (or polygonal detection structures if several structures are combined as will be described hereinafter).

It is also to be noted that the choice of the number of other detection devices between each of which and a given detection device, is connected a corresponding time-coincidence circuits, is dependent on several factors. For example, if (as in the embodiment described above) the polygonal structure comprises an even number of sides, the simplest realization would be to connect each time-coincidence circuit exclusively between a respective pair of detection matrices occupying a corresponding pair of opposite sides of the polygonal structure (thus, in the case of a hexagonal structure, between the matrices 1 and 4, 2 and 5, 3 and 6; in the case of an octagonal structure, between the matrices 1 and 5, 2 and 6, 3 and 7, 4 and 8; etc.). In the realization proposed for the embodiment described with reference to Figure 1 the image field of the apparatus is extended so as to be more

fully covered by also taking into account the annihilation of positrons detected by time-coincidence between a detection matrix which occupies a given side and respective matrices which occupy the sides adjacent to the side opposite said given side of the hexagonal structure (it is also possible to employ more than two additional coincidence connections if the number of sides of the polygonal structure is sufficiently large). In the case of a hexagonal structure, the time-coincidence detection can be provided between the matrices (1 and each of 3, 4, 5) (2 and each of 4, 5, 6), and so on. In the case of a polygonal structure comprising an odd number of sides (2n+1), the time coincidence could be provided, for example, between the matrices (1 and each of n, n+1, n+2, n+3) (2 and each of n+1, n+2, n+3, n+4) and so on.

When the detection matrices between which time-coincidence detection is provided are suitably chosen, the majority of positron annihilations occurring inside the sectional region or the organ under examination, can be taken into account. An even more elaborate embodiment is feasible in which positron annihilation events detected by time-coincidence between adjacent detection matrices, can be taken into account in order to subtract their effect from the effect of positron annihilations occurring between oppositely situated detection matrices. The number of such coincidences between adjacent matrices, corresponding to annihilations which seem to occur outside the field of view due to the relative location of the matrices considered, is found to be approximately equal to the number of spurious random coincidences which are observed within the sectional region or organ under examination, and which would falsify the final result of a tomographic examination. This provides a simple means of correcting for said disturbing time-coincidences.

For the embodiment described with reference to the Figures 1 to 3, this approach would lead to the additional provision of further time-coincidence circuit connections between the detection matrices (1 and each of 2, 6) (2 and each of 3, 1), (3 and each of 4, 2) and so on, in the hexagonal structure.

In the embodiments of the apparatus described above, a comparatively thin sectional region of a portion of a body or of an organ, can be examined in a direction transverse to an axis which in Figure 1 extends perpendicularly with respect to the drawing. When a plurality of identical polygonal structures are adjacently arranged along the axis or when bidimensional detection matrices with continuous position detection are provided, a form of apparatus is obtained which can enable reconstruction of respective images of a plurality of parallel sections instead of a single section of the region under examination. In the case of apparatus comprising several identical polygonal structures, shields can be arranged between said structures in order to provide some separation of radiation from the respective sections examined by means of each of the said structures, and time-coincidence circuits can be connected, as before, with respect to one and the same polygonal structure, between detection matrices associated with oppositely situated sides or substantially oppositely situated sides of two adjacent structures, or even associated with adjacent sides, depending on whether it is necessary simply to take into account all time coincidences observed in the zone examined, or whether the spurious random coincidences have also to be corrected for as described above.

In the case of an apparatus comprising bidimensional detection matrices, the geometrical resolution in a given direction can be made different from that in the other direction, for example, it being finer in the transaxial direction than in the axial direction.

CLAIMS

1. Positron emission transaxial tomography apparatus, comprising detector means which comprise a plurality of detector matrices, each detector matrix forming a corresponding side of a polygonal arrangement of said detector matrices surrounding an object region to be examined, and electronic signal processing means, which include coincidence, integration and discrimination circuits for forming an image of at least one sectional region of the object, characterized in that each of the detector matrices of the detector means is associated with a corresponding photon conversion element which is common to all the detectors of said matrix.

2. Tomography apparatus as claimed in Claim 1, characterized in that each of the detector matrices is constructed as a gamma camera which includes a photon conversion element adapted to the radiation to be detected, and a signal processing device.

3. Tomography apparatus as claimed in Claim 1 or 2, characterized in that each of the detection matrices is constructed as a cross-bar gamma camera.

4. Tomography apparatus as claimed in Claim 1, 2 or 3, characterized in that each coincidence circuit is connected to an instantaneously reading input circuit for an arithmetic unit.

5. Tomography apparatus as claimed in any one of the preceding Claims, characterized in that a coincidence circuit is provided between each of the detector matrices and at least one oppositely situated matrix.

6. Tomography apparatus as claimed in any one of the preceding Claims, characterized in that each of the detector matrices comprises a linear row of detectors which are situated in a detection plane which defines the sectional plane in respect of which a sectional image is to be formed.

7. Tomography apparatus as claimed in any one of the preceding Claims, characterized in that each of the detector matrices comprises a plurality of linear rows of detectors which are mutually parallel, and arranged adjacent one another in a

direction perpendicular to a detection plane which latter defines the direction of the sectional planes to be imaged.

8. Tomography apparatus as claimed in any one of the preceding Claims, characterized in that it comprises several, mutually shielded polygonal arrangements of detector matrices.

9. Positron emission transaxial tomography apparatus, substantially as herein described with reference to the accompanying drawings.

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